ODAK2023 Kick-Off Event

Sunrise for Concentrating Solar Thermal (CST) in Turkey
METU, Ankara, Turkey. 26th February 2020

Solar Desalination R&D Unit Activities at CIEMAT-PSA

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GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Research Topics

Objective: Development of new scientific and technological knowledge in the field of desalination and thermal separation processes powered by solar energy

Solar thermal cogeneration plants
(CSP+D)

Salinity gradient power generation
- Pressure retarded osmosis (PRO)
- Reverse electrodialysis (RED)

Low-capacity solar desalination
MD (Membrane Distillation)
FO (Forward Osmosis)

Brine and industrial wastewater thermal concentration
(ZLD)

High-capacity solar desalination
- LT-MED
- AHP-MED, ADS-MED
- TVC-MED

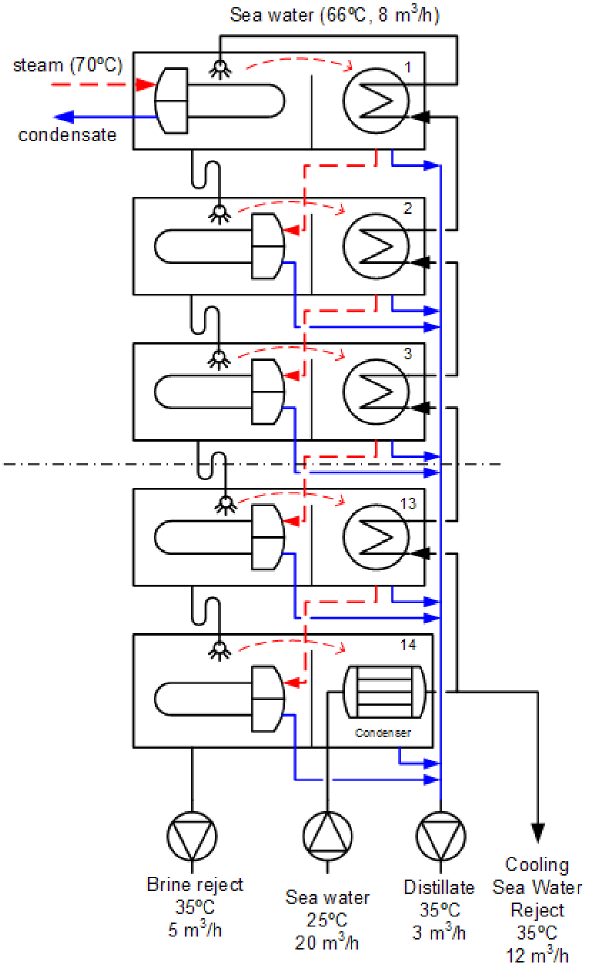
Solar water desalination processes

Dynamic modelling, optimization and advanced control in solar desalination processes

High-capacity solar desalination

Low-temperature Multi-Effect Distillation (LT-MED) process

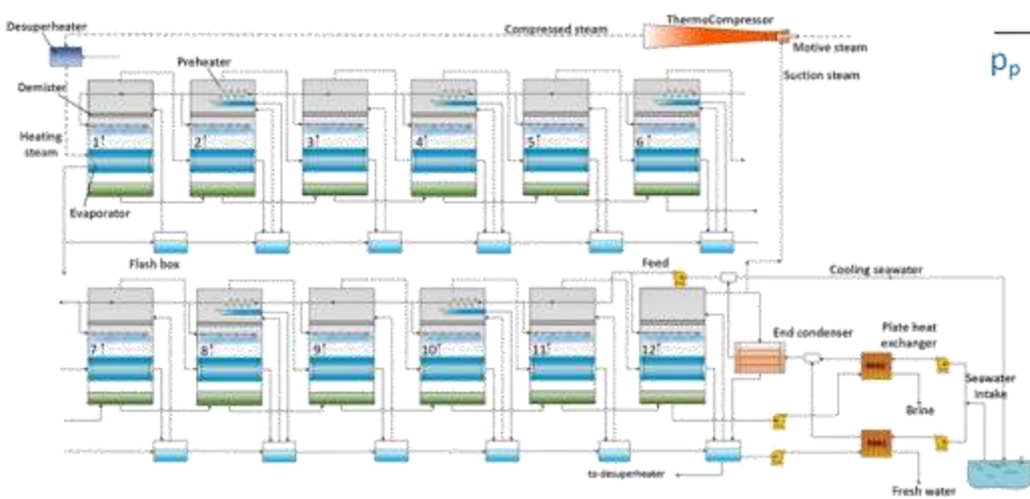
- Top Brine Temperature (TBT) = 70 ºC
- Conversion Factor (CF) = 37.5%
- Product water conc. < 5 ppm
- Thermal energy can be supplied by static solar termal collectors
- Thermal storage based on water
- Max. Gain Output Ratio (GOR) around 10-11 (58-64 kWh/m³)

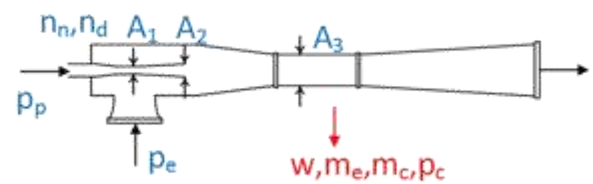


High-capacity solar desalination

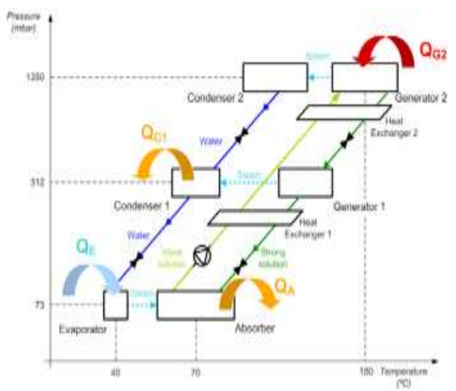
Multi-Effect Distillation with Thermo-Compression (TVC-MED)

- MED process coupling with steam ejectors for low-pressure heat recovery
- Temperature range: 130 – 330 ºC
- Solar powered by concentrating solar collectors or high-vacuum flat-plate collectors.
- Max. Gain Output Ratio (GOR) = 14-15 (36-38 kWh/m³)



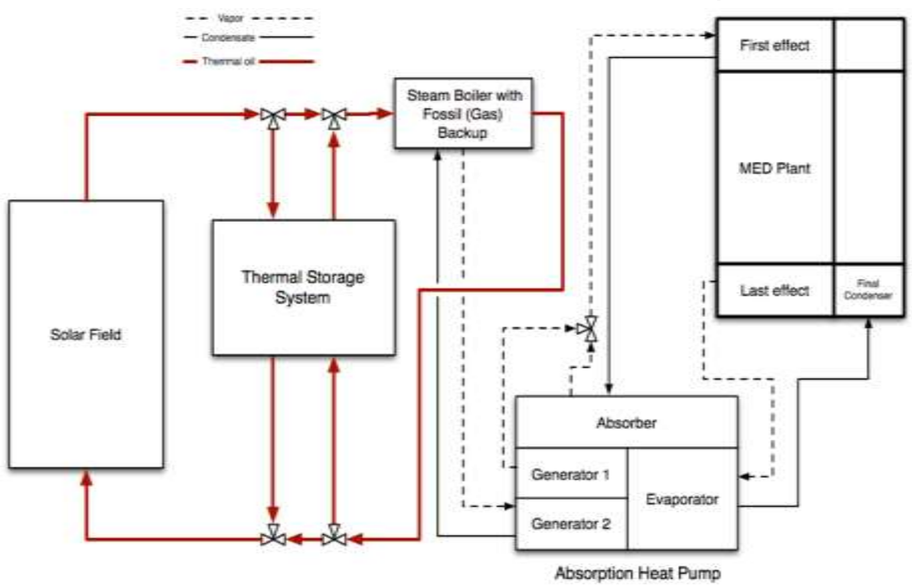


High-capacity solar desalination

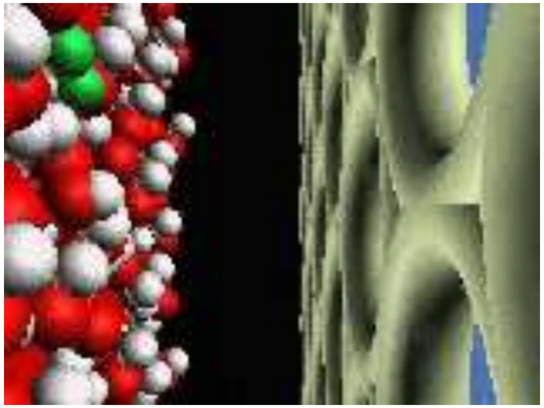


ABS-MED Process

- Coupling of Double-Effect Absorption Heat Pumps (LiBr-H_2O) to MED process for high-efficient low temperature heat recovery
- Max. temperature: 180 ºC
- COP = 1.2
- Max. GOR = 22 (~29 kWh/m^3)



Low-capacity solar desalination



Membrane Distillation (MD)

Membrane Distillation is an evaporative process in which water vapor, driven by a difference in vapor pressure, permeates through a hydrophobic membrane, thus separating from the salt water phase.

Once the vapor has passed through the membrane, it can be extracted or directly condensed in the channel on the other side of the membrane.

Advantages:

- The operating temperature is in the range of 60 to 80 °C.
- The membranes used in MD are **tested against fouling and scaling**.
- **Chemical** feed water **pre-treatment is not necessary**.
- **Intermittent operation** of the module is **possible**. Contrary to reverse osmosis (RO), there is no danger of membrane damage if the membrane falls dry.
- **Lower operating pressure** than RO process.
- **100% theoretical salt rejection**; system efficiency and quality are independent of salinity of the feed water.
- Less space and equipment requirements compared to those of thermal processes that result in capital savings.

Low-capacity solar desalination

UDeS

SCARAB DEVELOPMENT AB

Membrane Distillation characterization at module level

2005

CF = 1%
GOR = 0.7

Keppel Seghers

CF = 2%,
GOR = 0.4

CF = 4%
GOR = 1.5

CF = 5%
GOR =3.2

CF = 40%, GOR =4.1

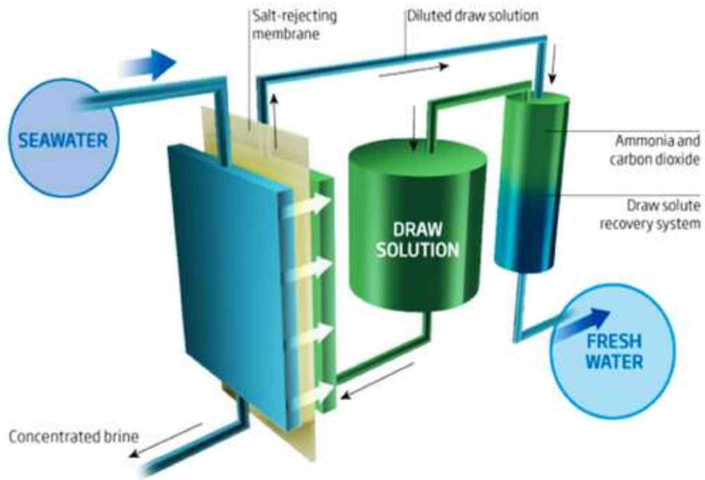
CF = 6.5%
GOR =13.5

CF = 5.8%
GOR = 4.8

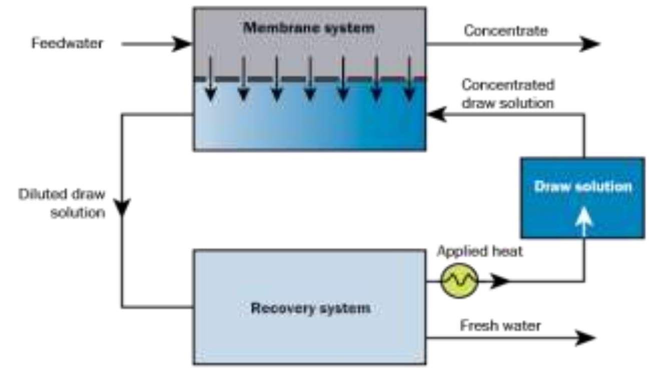
2020

Low-capacity solar desalination

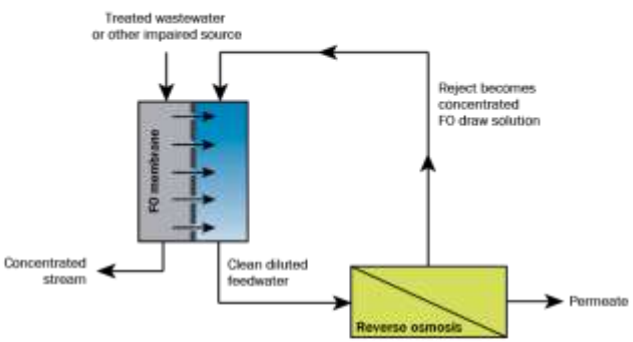
Forward Osmosis (FO)



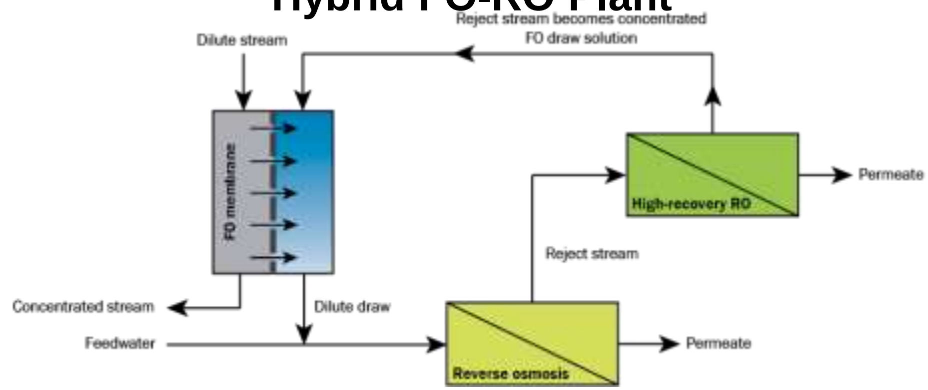
FO in brine concentration processes



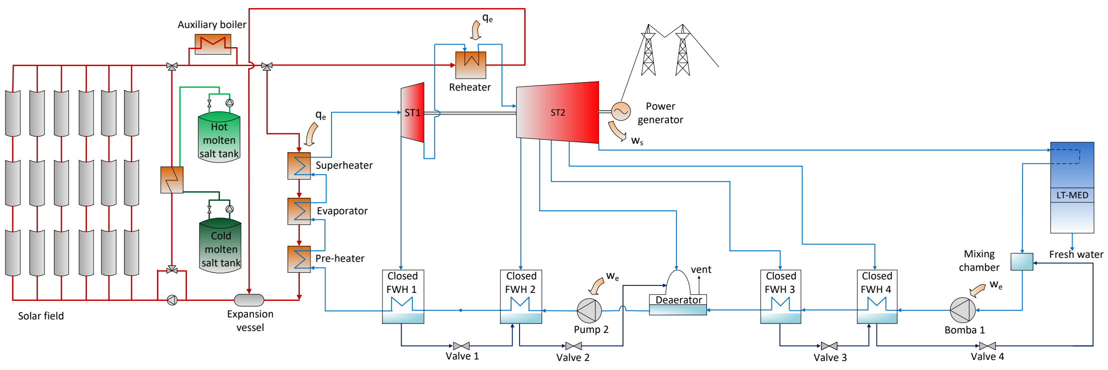
Example of FO as pretreatment of RO

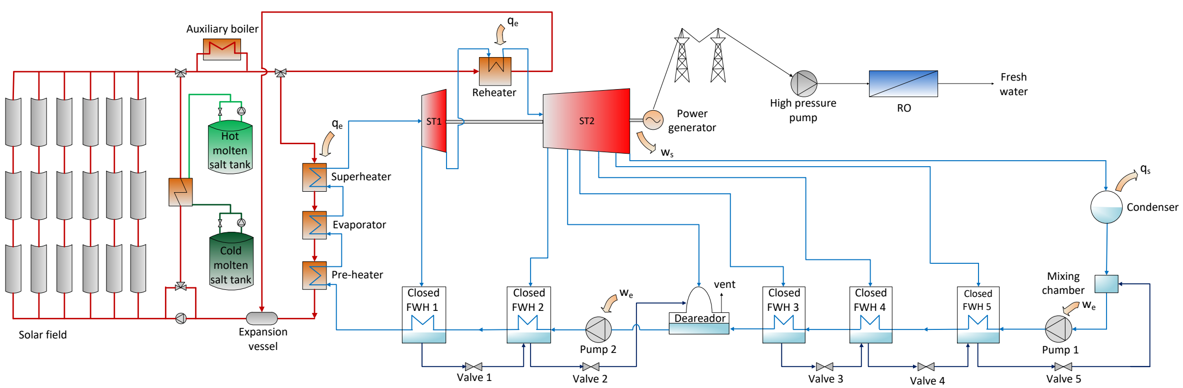


Hybrid FO-RO Plant



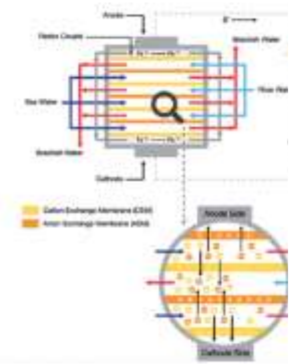
CSP + Desalination (CSP+D)

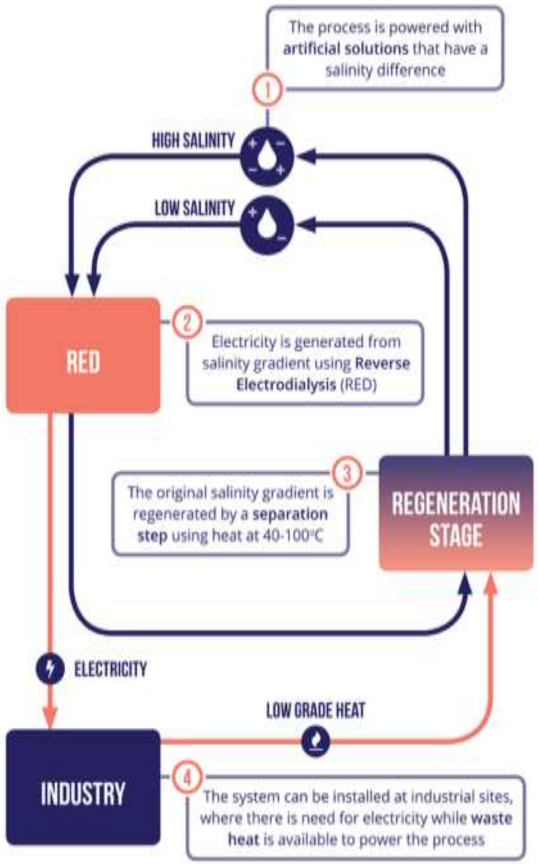




- Research line in the field of **simultaneous production of electricity and desalinated water** using **solar thermal concentrating technologies**
- Main objective: To answer the basic question of when a **solar thermal cogeneration scheme** has better techno-economic viability than the **independent** production of fresh water and electricity

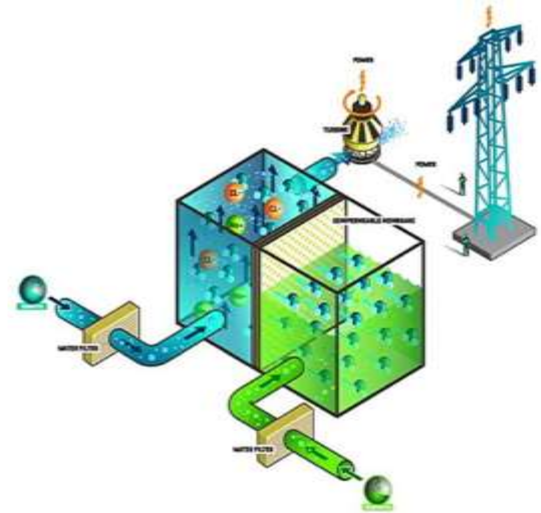
Salinity gradient power generation



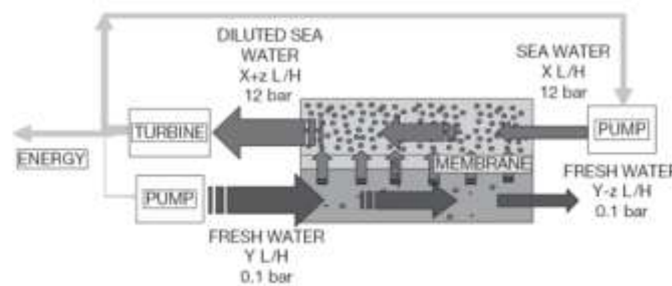


Close-loop reverse electrodialysis (RED)

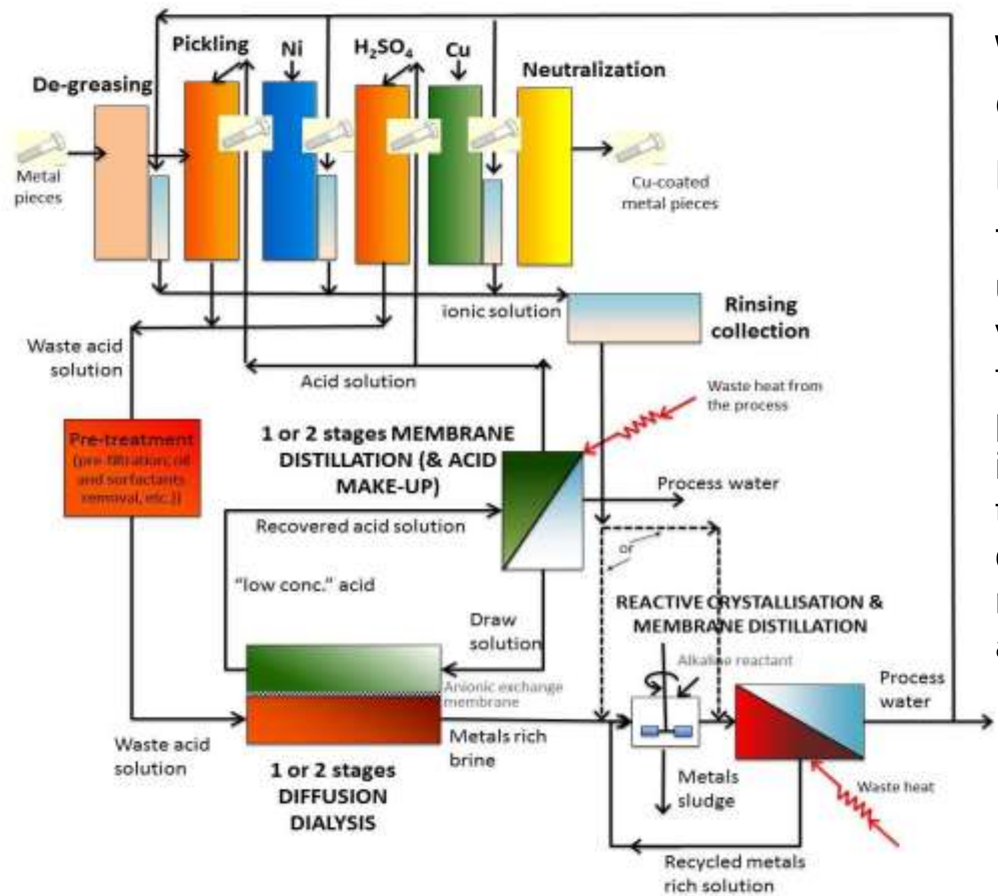
Pressure-retarded osmosis (PRO)



L. Panyor / Desalination 199 (2006) 408–410



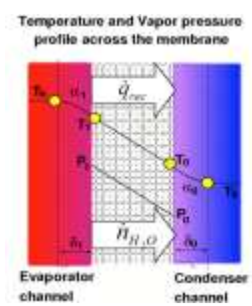
Thermal separation processes



Brine and industrial wastewater thermal concentration

Example: REWACEM Project (H2020)

The ReWaCEM project aims at reducing water use, wastewater production, energy use, valuable metal resource recovery and water footprint by between 30-90% in the metal plating, galvanizing and printed circuit board industry. Two cutting edge membrane technologies (**membrane distillation and diffusion dialysis**) selected for the requirements of closed material cycles approaches and recovery concepts.



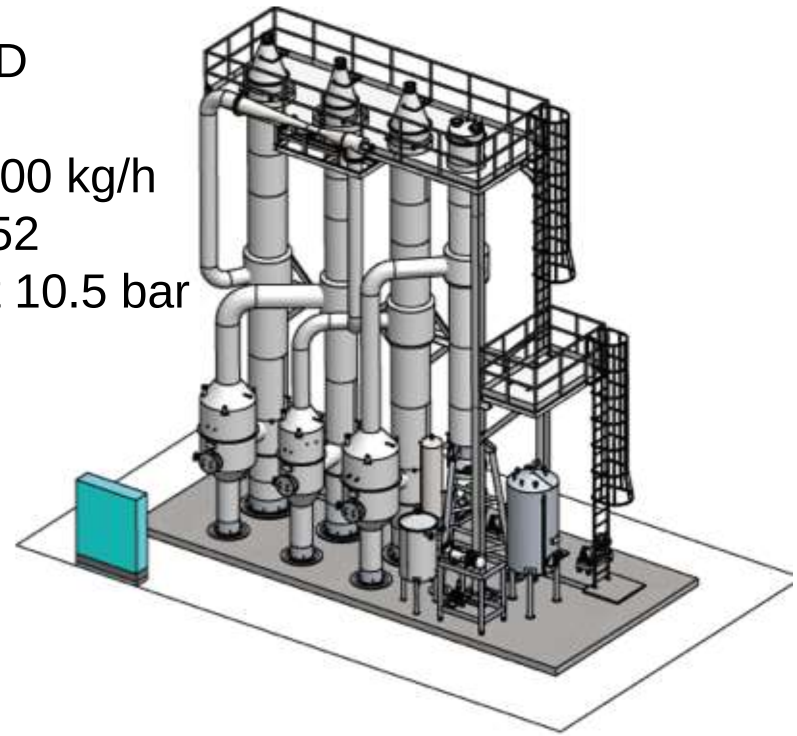
Thermal separation processes

SOLWARIS Project (H2020) will demonstrate the efficiency of using a **Multiple Effect Evaporation** (MEE) system to recycle and re-use 90% of these wastewater streams using thermal energy otherwise dumped by defocusing parts of the solar field.

<u>Wastewater Streams</u>

1- R.O. Rejection water
2- Cooling tower blowdown
3- Turbine blowdown
4- Final discharge basin

TVC-MED
3-effects
Feed=8000 kg/h
GOR=3,52
Steam at 10.5 bar



95% of recovery rate can be achieved in all samples from La Africana and Shagaya CSP Plants

Thermal separation processes

R&D Activities at membrane level

Bench-scale unit for test MD applications in air-gap, permeate-gap and direct contact configurations

Bench-scale unit for flat sheet membrane distillation testing

Bench-scale unit for test with 2-stage forward osmosis and pressure retarded osmosis

Human Resources

Senior researchers (Permanent)

- Dr. Diego-César Alarcón-Padilla
- Dr. Guillermo Zaragoza
- Dr. M. Ignacio Maldonado Rubio

Senior researchers (Project fund.)

- Dra. Patricia Palenzuela
- Dra. Lidia Roca
- Dr. Javier Bonilla

Post-doc researchers (CIESOL)

- Dr. Bartolomé Ortega Delgado
- Dr. Juan Antonio Andrés-Mañas

Thank you very much for your attention!

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